Transport of Optically Active Particles from the Surface Mixed Layer: Losses Due to Grazing and Focculation During the Chalk-Ex Study

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LONG-TERMS GOALS

To determine the mass balance of optically active particles within the surface boundary layer and to identify processes responsible for their redistribution.

OBJECTIVES

1) To perform manipulative experiments in which a known quantity of optically active $CaCO_3$ particles are introduced into the surface mixed layer, and tracked over time and space. This approach effectively removes uncertainty in the production term of the mass balance equation.

2) To quantify the loss from the mixed layer of optically active particles due to grazing and aggregation.

APPROACH

In addition to the work by Dam and McManus, there is close collaboration with Drs. W.M. Balch and C. Pilskaln (Bigelow Lab for Ocean Sciences/Optical and vertical flux studies) and Dr. A. Pluddemann (WHOI/ physical studies). Their work is not included in this report.

In November 2001, we participated in a 10-day cruise in the Gulf of Maine and the slope waters in the Western North Atlantic Ocean. During the cruise, we participated in the deployment of two chalk patches and conducted bottle experiments to investigate the fate of the chalk with regard to processes such as grazing and aggregation. In addition to this field component, laboratory observations on chalk/grazer interactions are ongoing.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2002		**00-00-2002 to 00-00-2002**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Transport of Optically Active Particles from the Surface Mixed Layer: Losses Due to Grazing and Focculation During the Chalk-Ex Study	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Department of Marine Sciences,,University of Connecticut,1080 Shennecossett Rd.,,Groton,,CT, 06340**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
To determine the mass balance of optically active particles within the surface boundary layer and to identify processes responsible for their redistribution.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**6**	

WORK COMPLETED

Grazing. During the Chalk-Ex cruise in November, 2001, we conducted five bottle incubations on deck while the artificial chalk patches were being followed. Experiments consisted of four treatments. For all treatments, one-liter polycarbonate bottles were filled with water pre-screened through 200 µm mesh by reverse flow. Three of the treatments received added mesozooplankton in successively greater multiples of the natural abundance, up to c. 32x. The experiments were designed to look for evidence of microzooplankton grazing (removal of chalk-sized particles in the <200 µm treatment) and either top-down control by mesozooplankton (grazing on chalk-sized particles declines as mesozooplankton concentration increases) or direct mesozooplankton grazing (grazing on chalk-sized particles increases with mesozooplankton concentration). Abundance of chalk-sized particles (1.3-3.5 um) was measured with an Elzone particle counter at initial and final (c. 20h) experimental times. We also had formalin-killed controls, but they showed evidence of particle production during the experiments, most likely due to mineral precipitation of the preservative's buffer, and were thus difficult to interpret.

Flocculation. During the same cruise we measured the flocculation rates of particles assemblages, from waters in the chalk patches, in Couette devices (Drapeau et al., 1994, Dam and Drapeau, 1995) by monitoring the changes in mean particle size with time. Measurements were done on five separate occasions in triplicate incubations lasting 5-6 h each. The shear rate in the Coutte devices was 6 s^{-1}. We employed two kinds of devices to measure particle size—an electric impedance device (ElZONE 280 particle counter) and a laser counter (GALAI). Both of these devices can resolve particles as small as 0.5 µm. The chalk particle size ranged from 1.3 to 3.5 µm.

RESULTS

Grazing. Net per capita rates of change for chalk-sized particles ranged from –0.89 to +0.47 d^{-1} in the <200 µm treatment during the five experiments (fig. 1). Three of the five experiments showed evidence of top-down control on microzooplankton grazing. Because the chalk size-fraction also contained coccoid cyanobacteria and heterotrophic bacterioplankton, which presumably were growing during the incubations, any net losses would provide minimal estimates of potential grazing on chalk. For several experiments, chalk particles were abundant enough to count directly using a polarized light microscope. These observations suggested real net loss of chalk particles in the bottles. Because processes other than grazing might have contributed to loss of chalk particles in the bottles (e.g. dissolution or aggregation). We plan future work on possible chalk ingestion by protists using laboratory cultures. Preliminary observations with a large heterotrich ciliate, *Condylostoma sp*., in laboratory culture, indicate that this species will ingest chalk.

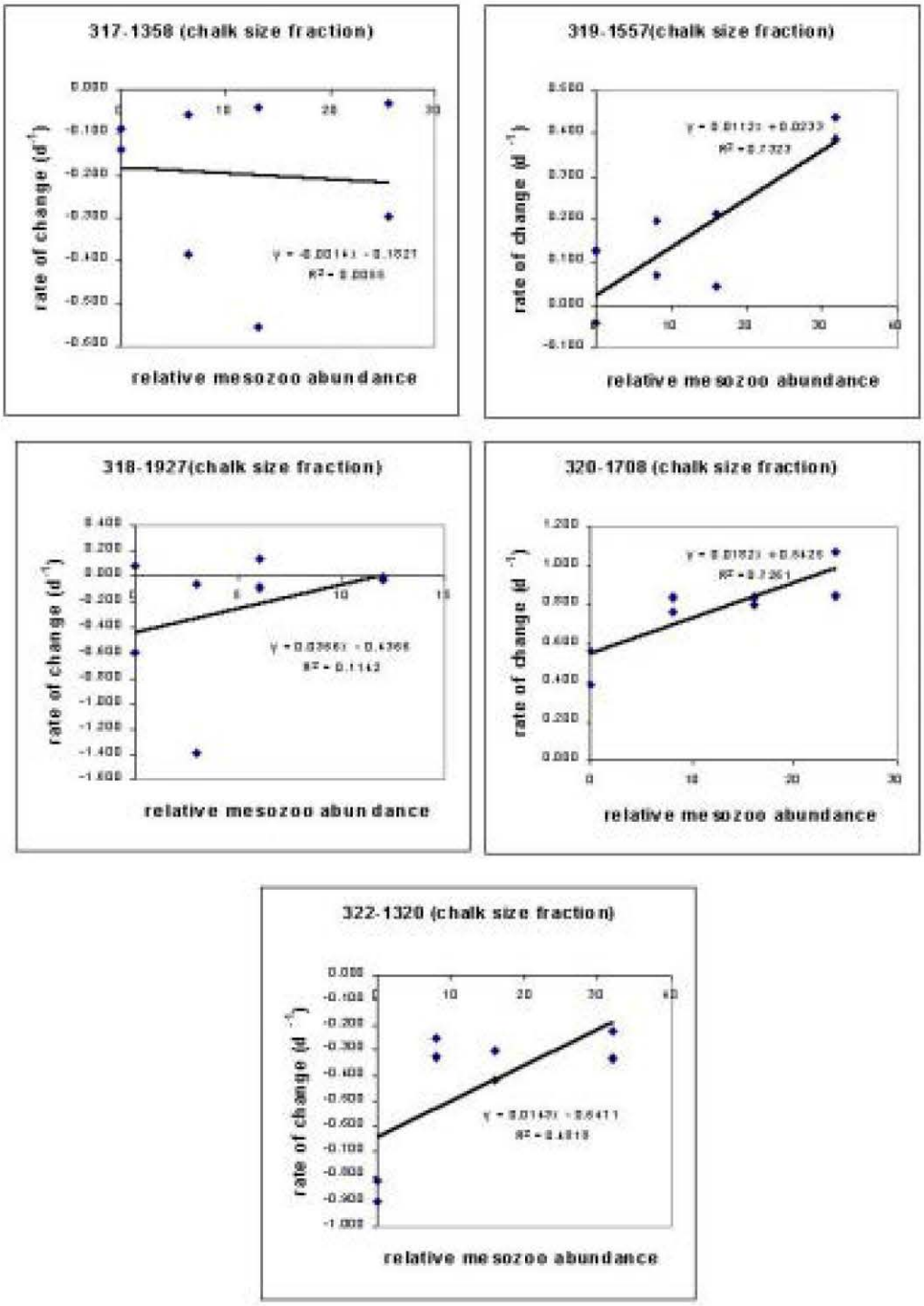

Figure 1. Plots of mesozooplankton abundance vs. net rate of change of chalk-sized particles (1-3 µm) in the five bottle experiments. The value at zero on the x-axis indicates the rate of change due to microzooplankton (<200 µm). As the relative abundance of mesozooplankton increases, the rate of change should decrease if these larger grazers are ingesting the chalk, or increase if they are instead primarily grazing on the microzooplankton that are ingesting the chalk.

Flocculation. Our experiments on particle flocculation were predicated on the assumption that volume is conserved during aggregation. Hence, in a closed system (as in the Couette devices) as aggregation takes place, mean particle size increases with time. We observed very good agreement between both instruments in characterizing particle size during the incubations. Furthermore, we also observed particle size increase with time during all of our five separate incubations, as illustrated in the particle size spectra shown in Fig. 2. That is, the slope of the line for each spectrum decreased with time. These changes in spectra translate to a 2.5–fold increase in mean particle volume during the length of the 5-6 h incubation. However, it is also evident that volume was not conserved during the incubations since the Y-intersect of the spectra increased with time. This was characteristic of all five incubations during the cruise. Two possible explanations account for the lack of volume conservation in the incubations. One is that aggregates were fractal. The other is that new particles were formed during the incubations, either from bacterial or phytoplankton growth, or from aggregation of colloids. In any case, the results obtained here pose a challenge to characterizing the chalk aggregation with classical flocculation theory.

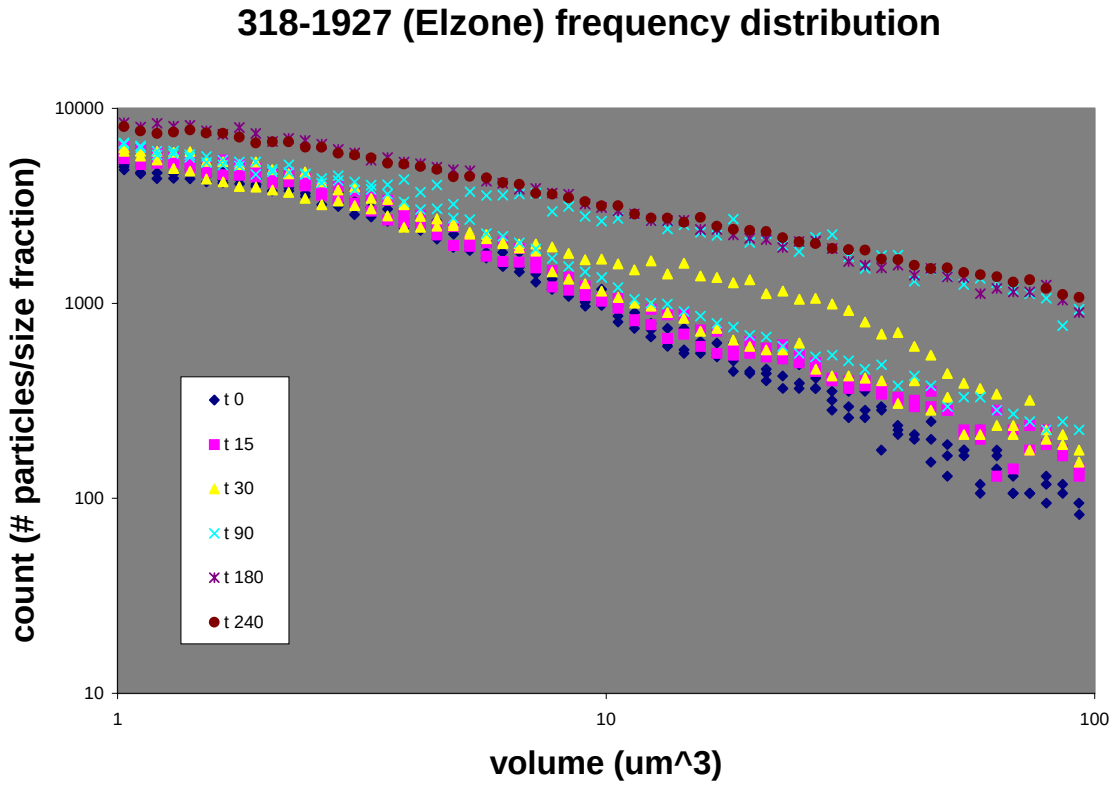

Figure 2. Mean particle volume (X-axis) versus particle abundance (counts/0.2 ml) for each size fraction (Y-axis) as a function of time. The slope of each line decreases with time indicating aggregate formation during the incubations. The Y-intersect for each line also increases with time, indicating that volume is not conserved during the incubations.

IMPACT/APPLICATIONS

Our experiments are designed to identify the relative importance of two loss terms—grazing and aggregation—on the mass balance of coccoliths, an important group of optically active particles. Without this information the evolution of the underwater field and prediction of underwater visibility on the spatial (1-10,000m horizontal and 1-100 m vertical) and temporal scales (hours to days) of coccolithophore blooms is severely hindered.

TRANSITIONS

None.

RELATED PROJECTS

We work as a part of a team with the other PI's in this project: Drs. Balch and Pilskaln (Bigelow Laboratory for Ocean Sciences) and Dr. Pluddemann (WHOI).

REFERENCES

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